Textures of the Carboniferous Ignimbrites in the Hunter Valley, N.S.W.

B. Nashar and A. T. Brakel

ABSTRACT. Rocks of the Carboniferous calc-alkaline volcanic series in the Hunter Valley, New South Wales, possess well-defined eutaxitic devitrification and possibly vapour-phase textures and show varying degrees of welding and compaction. The devitrification and vapour-phase textures comprise axiolitic, spherulitic, granular and granophyric forms. The eutaxitic textures suggest that the ignimbrites were emplaced by an ash-flow mechanism with welding commencing after the flow came to rest accompanied by compaction due to the overlying lithostatic load.

INTRODUCTION

Occurring within the Hunter Valley is a petrographic province of Carboniferous volcanic rocks of the andesite-dacite-rhyodacite-rhyolite association, first described in a series of papers by Osborne (1922a, 1922b, 1925, 1927, 1928a, 1928b), Browne (1927) and Scott (1948). As indicated in Figure 1 the Carboniferous rocks crop out in a belt which extends beyond the Hunter Valley in a northwesterly direction between Tamworth and Gunnedah to east of Moree. The volcanics were developed extensively and regularly throughout the Carboniferous System from Upper Viséan to Upper Stephanian time. Scott (1948) and Osborne (1950) first recognised some of these rocks as ignimbrites.

ROCK TYPES AND MINERALOGICAL COMPOSITION

The rocks range in composition from pyroxene andesite (approx. 59% SiO₂) to rhyolitic ignimbrite (approx. 78% SiO₂). The pyroxene andesites are the only rocks which can be identified as normal lavas. The others are either ignimbrites or devitrified rock whose original texture has been obscured.

Because the magmatic history of the rocks does not favour equilibrium between phenocrysts and groundmass the mineralogical composition and proportion of the phenocrysts do not reflect the chemical composition. Quite acid rocks contain plagioclase and ferromagnesian phenocrysts expected from a more basic magma. The acid components are 'hidden' in the groundmass. On the basis of chemical analyses Nguyen (1976) has termed the rocks pyroxene andesite, hornblende dacitic ignimbrite, rhyodacitic ignimbrite and rhyolitic ignimbrite. Their phenocryst assemblage and percentage and groundmass percentage are given in Table 1.

The term ignimbrite is used by the authors in the same way as ash flow tuff is used by Ross and Smith (1961). The term includes welded tuff because, as will be seen below, the ash flow tuff may be unwelded, partially welded or densely welded.

MODE OF OCCURRENCE

The Carboniferous ignimbrites in the Hunter Valley occur usually in lithological units ranging

<table>
<thead>
<tr>
<th>ROCK TYPES</th>
<th>PHENOCRYST AND GROUNDMASS PERCENTAGE</th>
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<tbody>
<tr>
<td>pyroxene andesite</td>
<td>(21% phenocrysts, 79% groundmass)</td>
</tr>
<tr>
<td>hornblende dacitic ignimbrite</td>
<td>(15% phenocrysts, 85% groundmass)</td>
</tr>
<tr>
<td>rhyodacitic ignimbrite</td>
<td>(12% phenocrysts, 88% groundmass)</td>
</tr>
<tr>
<td>rhyolitic ignimbrite</td>
<td>(5% phenocrysts, 95% groundmass)</td>
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</table>

CONCLUSIONS

1) By a mechanical cleaning process of chrysotile fibres all other serpentine minerals are removed from clino-chrysotile.

2) Clinochrysotiles from Advocate and Balangero are resistant to hydrothermal treatment; but in those from Zidani antigorite is formed.

3) The dust-fraction contains significantly more chrysotile if treated hydrothermally.

4) With the exception of magnetite accessory minerals are removed by mechanical cleaning and hydrothermal treatment from the fibre, but not from the dust-fraction. Contaminating minerals, which are epitactically intergrown with fibres, are hydrothermally dissolved.

5) Some minor and trace elements - such as aluminium - are located in the chrysotile structure and their amounts are neither mechanically nor hydrothermally influenced.

6) The gibbs free energy of the three kinds of fibres investigated differ by 2.5 kcal/mole. The calculated activation energies for the dissolution of magnesium and silicon demonstrate that these processes are typical of diffusion from the fibre surface into solution.

7) The surface of chrysotile fibres is of importance to their mechanical properties. Fibres with high positive surface charges show good mechanical qualities and are hydrothermally resistant. Fibres with low positive surface charges, however, change their potentials to negative values and are able to absorb positively charged complexes.

Summarizing: chrysotile fibres with high surface charge, such as Advocate, are suitable for the manufacture of asbestos cement products; fibres with low surface potentials, such as Zidani, should be more advantageous for the development of composite materials.

ACKNOWLEDGEMENTS

We are grateful to Eternit S.A., Belgium and its director A. Gosseye for financial support and Professor P. Ney, University of Cologne for instrumental help.

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CHrysotile ASBESTOS

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<td>2</td>
<td>2</td>
<td></td>
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<td></td>
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<tr>
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<td>10</td>
<td>3</td>
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<td>77</td>
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<tr>
<td>Hornblende dacitic ignimbrite</td>
<td>rare</td>
<td></td>
<td>27</td>
<td>2</td>
<td>6</td>
<td>3</td>
<td>rare</td>
<td>2</td>
<td>60</td>
</tr>
<tr>
<td>Pyroxene andesite</td>
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<td></td>
<td></td>
<td></td>
<td>7</td>
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<td>3</td>
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Fig. 1. Distribution in New South Wales of Carboniferous rocks in which ignimbrites occur.
in thickness from a few metres to about 100m but some are greater. For example, the Mt Bright Rhyolitic Ignimbrite Member near Pokolbin (Brakel, 1973) has been estimated to be about 460m thick and the Paterson Volcanics at Mt Tangorin 310m (Slee, 1968). The aerial extent also varies. Some, such as the Mirannie Volcanic Member and Paterson Volcanics, cover a considerable area and have been used as marker units for a distance of up to 65km. Some units comprise one ash flow while others are multiple and comprise two or three.

Terminations of ignimbrite units have been observed and in all instances the rock grades into an agglomerate in which phenocrysts of rounded volcanic material in places exceed by volume the proportion of matrix. Tuffs and tuff breccias are associated with the agglomerate. The units become thinner until they lens out.

**TEXTURES**

In hand specimen the rocks are porphyritic. The phenocrysts average about 4mm in size and are set in either aolithic or vitroelastic groundmass which is generally quartzo-feldspathic in composition wherever devitrification has occurred. The plagioclase phenocrysts in the lighter coloured rocks are often pink in colour. The rhyolitic ignimbrites often contain abundant pumiceous fragments (Plate IA).

The lithoidal varieties vary in colour depending upon the degree of alteration. The more acid rocks are buff, pink, cream or white but when fresh are usually dark grey as are the andesites. Occasionally, the ignimbrite may be light to dark green in colour due to the presence of secondary caldonite in the matrix. The vitric varieties are black, or greenish black, pitchstones and are often cross-cut by dark red devitrified and haematitized layers. These rocks, when weathered, take on a brick red lithoidal appearance.

Under the microscope, phenocrysts, particularly of quartz, are usually seen to be resorbed and embayed and it is not uncommon for those of biotite and hornblende to be resorbed and their former presence marked by granules of magnetite. The abundance of phenocrysts varies from 5 to 55%.

The groundmass of all rock types except the pyroxene andesites is usually eutaxitic and examples of poorly welded, moderately welded and strongly welded ash flow tuffs abound (Plate IB, C, D, E, F).

The shapes of the shards in thin section are mostly cuspat but Y, U or C and O shapes are common. The shape depends upon the degree of initial fragmentation, subsequent compaction of the ash flow tuff and plane of section. In the loosely compacted rocks, complete bubble shapes and bubbles in various stages of fragmentation can be clearly seen (Plate IB, C).

In many cases compaction has resulted in the shards being compressed against or even moulded around the phenocrysts (Plate IF).

Pumice and lithic fragments of variable size (up to 25mm) are common and these, too, are frequently elongated and aligned parallel with the shards. Often, the ends of the pumice fragments are frayed.

Devitrification of shards and pumice is commonly developed. The most usual forms are aholitic (Plate IIA), granular (Plate IIB) and spherulitic. The crystallization within the spherulitic form is of three types. The first comprises radiating fibres. In the ignimbrites it is sometimes difficult to discern the shape of the spherules when viewed in plane light but when the nicoils are crossed the radiating fibres are seen to cut across the shards. The second, although resembling the radiating type in ordinary light (Plate IIE) is seen to have a granular texture when observed between crossed nicoils (Plate IIF) while the third, again indistinguishable from the first two types in plane light (Plate IIC) reveals granophyric texture between crossed nicoils (Plate IID). The latter two types occur in the rhyolitic lavas and there is a possibility that they may be the result of vapour-phase crystallization rather than the products of devitrification.

Vapour-phase crystallization has been described by Brakel (1967), Marchoni (1968) and Frater (1970). This consists of silica mineralization in cavities in the Y- and O-shaped shards and small accumulations within what are believed to be pore spaces between gas bubbles. The quartz granules are coarser than those of the devitrification products. Whether these and/or the spherules in the rhyolites are vapour-phase phenomena is uncertain. If they are, the original form of silica would probably have been cristobalite and/or tridymite which has inverted to quartz.

Granophyric crystallization has been observed in fine-grained Carboniferous acid rocks from the Gloucester District but no trace of eutaxitic texture is evident in them. Whether their texture represents a coarser than usual devitrification product or primary crystallization from an intrusive melt could not be determined.

**SIGNIFICANCE OF THE TEXTURES**

In spite of their age, these Carboniferous lithoidal and vitric volcanic rocks possess well-defined eutaxitic and devitrification textures typical of younger ignimbrites found and described elsewhere.

According to Smith (1960), ignimbrites have been emplaced as hot avalanche-type masses, which probably contained hot gases, and therefore may have been to a greater or less extent autoexplosive. Welding commenced after the flow came to rest and was accompanied by compaction due to the overlying lithostatic load, resulting in shards of glass (or devitrified glass) and fragments of pumice and rock being aligned in a parallel arrangement as indicated in Plate IA, D, E, F.

Using Smith's (1960) model of zones of welding which requires zones of no welding at the base and top of the cooling unit and zones of partial welding separating these from a central zone of dense welding, the degree of welding of the shards indicates the position of the specimen within a cooling unit. Thus, not only the zonal pattern within the
unit may be determined but also the cooling units themselves may be defined. To give two examples, Brakel (1973) has recorded the thick Mt Bright Rhyolitic Ignimbrite Member near Pokolbin which shows a gradation from loosely welded texture at its base to extreme welding at its top. At the top of the unit is an unconformity, indicating that the upper, less strongly welded zones have probably been removed by erosion. Prater (1970) has successfully defined welding zones in ash flow tuffs in the Rouchel Brook-Back Creek Area according to Smith’s model.

The eutaxitic texture of most of the rocks suggests that they were emplaced by an ash-flow mechanism. The ash-flows, similar to nuSes ardentes, are regarded as mixtures of gas-emitting shards and pumice shreds, with some lithic fragments. At the base and top of the flows, where the opportunity for the loss of heat and volatiles was greatest, the shards became rigid soon after being formed and consequently the material deposited was unwelded or poorly welded. In the centre of the ash-flows, because of the higher concentration of volatiles and heat, the shards and pumice fragments were still in a plastic state when the flows came to rest, and welding took place aided by lithostatic load.

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PLATE I
A Pumiceous fragments in rhyolitic ignimbrite (Scone 310975)
B Non welded rhyodacitic ignimbrite. Plane light (Camberwell 352992)
C Poorly welded rhyodacitic ignimbrite showing various shapes of shards. Plane light (Camberwell 352992)
D Moderately welded rhyodacitic ignimbrite. Plane light (Camberwell 171982)
E Strongly welded rhyodacitic ignimbrite. Plane light (Camberwell 101971)
F Very strongly welded rhyodacitic Ignimbrite showing compaction of shards around phenocrysts. Plane light (Camberwell 258985)

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